Amendments to the Claims

This listing of claims will replace all prior versions, and listings of claims in the application.

Listing of Claims:

1. (Currently amended) An apparatus for generating a substantially controllable plasma, the apparatus comprising:

a) at least one plasma source, said at least one plasma source comprising a plasma chamber in which said substantially controllable plasma is generated, at least one cathode and an anode disposed in said plasma chamber, said at least one cathode and said anode being separated by a gap, said gap being adjustable, a power source coupled to said anode and said at least one cathode for providing a voltage across said anode and said at least one cathode, a plasma gas inlet for introducing a plasma gas from a plasma gas source into said plasma chamber at a plasma gas flow rate, and a sensor for monitoring conditions within said plasma chamber, said sensor being integral to said plasma chamber; and

b) a second chamber in fluid communication with said plasma chamber through an exit port, wherein said second chamber is maintained at a second pressure that is less than a first pressure in said plasma chamber, and wherein said substantially controllable plasma flows from said plasma chamber into said second chamber through said exit port.

2. (Original) The apparatus according to Claim 1, wherein the plasma source is an expanding thermal plasma source.

3. (Original) The apparatus of Claim 1, wherein said plasma gas inlet further includes means for controlling a flow of said plasma gas into said plasma chamber.

4. (Currently amended) The apparatus of ~~Claim 1~~ Claim 3, wherein said means for controlling said flow includes at least one mass flow controller.

5. (Original) The apparatus according to Claim 1, wherein said apparatus comprises a first plasma source and a second plasma source, wherein said first pressure of

said plasma gas in said plasma chamber in said first plasma source and said first pressure of said plasma gas in said plasma chamber in said second plasma source are adjustable with respect to each other.

6. (Original) The apparatus according to Claim 1, wherein said sensor is a pressure sensor, said pressure sensor being in fluid communication with said plasma chamber.

7. (Original) The apparatus according to Claim 6, wherein said pressure sensor comprises a transducer.

8. (Original) The apparatus according to Claim 1, wherein said sensor is one of a current sensor and a voltage sensor disposed in an electrical circuit between said power source and said cathode.

9. (Original) The apparatus according to Claim 1, wherein said power source is a DC power source.

10. (Original) The apparatus according to Claim 9, wherein said power source provides up to 100 amps of current at up to about 50 volts.

11. (Original) The apparatus according to Claim 1, wherein said exit port comprises an orifice formed in said anode.

12. (Original) The apparatus according to Claim 1, wherein said exit port comprises a floating cascade plate.

13. (Original) The apparatus according to Claim 1, wherein said exit port comprises a floating wall of one of said plasma chamber and said second chamber.

14. (Original) The apparatus according to Claim 1, wherein said apparatus is an apparatus for plasma treating a surface of an article with said substantially controllable plasma, wherein said article is disposed in said second chamber such that said substantially controllable plasma generated by said at least one plasma source exits said plasma chamber through said exit and impinges upon said surface.

15. (Original) The apparatus according to Claim 14, further including at least one reactant gas injector disposed in said second chamber proximate to said exit port of each of said at least one plasma source, wherein said reactant gas injector directs a reactant gas

into said substantially controllable plasma, and wherein said reactant gas reacts with said substantially controllable plasma to form a coating on said surface of said article.

16. (Original) The apparatus according to Claim 1, wherein said apparatus comprises a first plasma source and a second plasma source, wherein said voltage across said cathode and said anode in said first plasma source and said voltage across said cathode and said anode in said second plasma source are adjustable with respect to each other.

17. (Currently amended) A plasma source for generating a substantially controllable plasma, said plasma source comprising:

a) a plasma chamber in which said substantially controllable plasma is generated;

b) an anode disposed at a first end of said plasma chamber, said first end having an exit port through which said substantially controllable plasma exits said plasma chamber;

c) at least one adjustable cathode disposed in said plasma chamber, wherein said at least one adjustable cathode is movable to establish a gap between said anode and said at least one adjustable cathode;

d) a power source coupled to said anode and said at least one adjustable cathode for providing a voltage across said anode and said at least one adjustable cathode;

e) a plasma gas inlet for introducing a plasma gas from a plasma gas source into said plasma chamber at a plasma gas flow rate; and

f) at least one sensor for detecting and monitoring conditions within said plasma chamber, said sensor being integral to said plasma chamber.

18. (Original) The plasma source according to Claim 17, further comprising a pressure adjustment means for moving said at least one adjustable cathode, said pressure adjustment means being coupled to said adjustable cathode.

19. (Original) The plasma source according to Claim 18, wherein said pressure adjustment means is a pressure plate.

20. (Original) The plasma source according to Claim 18, wherein said pressure adjustment means is a pneumatic drive.

21. (Original) The plasma source according to Claim 17, further comprising a screw feed for moving said at least one adjustable cathode, said screw feed being coupled to said adjustable cathode.

22. (Original) The plasma source according to Claim 17, wherein said at least one adjustable cathode comprises a wire.

23. (Original) The plasma source according to Claim 22, further comprising a wire feed for moving said at least one adjustable cathode, said wire feed being coupled to said adjustable cathode.

24. (Original) The plasma source according to Claim 17, wherein said at least one sensor includes a pressure sensor, said pressure sensor being in fluid communication with said plasma chamber.

25. (Original) The plasma source according to Claim 24, wherein said pressure sensor comprises a transducer.

26. (Original) The plasma source according to Claim 17, wherein said at least one sensor includes one of a current sensor and a voltage sensor disposed in an electrical circuit between said power source and said cathode.

27. (Original) The plasma source according to Claim 17, wherein said power source is a DC power source.

28. (Original) The plasma source according to Claim 27, wherein said power source provides up to 100 amps of current at 50 volts.

29. (Original) The plasma source according to Claim 17, wherein said plasma gas inlet further includes means for controlling a flow of said plasma gas into said plasma chamber.

30. (Original) The plasma source according to Claim 29, wherein said means for controlling said flow comprises at least one mass flow controller.

31. (Original) The plasma source according to Claim 17, further including a control system for moving said at least one adjustable cathode, wherein said control

system is coupled to said at least one sensor, said power source, and said at least one adjustable cathode, wherein said controller receives an input on said conditions in said plasma chamber and moves said at least one adjustable cathode to establish a predetermined gap between said anode and said at least one adjustable cathode based upon said input.

32. (Original) The plasma source according to Claim 17, wherein said voltage is adjustable.

33. (Currently amended) An apparatus for generating a substantially controllable expanding thermal plasma, said apparatus comprising:

a) at least one expanding thermal plasma source, said at least one expanding thermal plasma source comprising: a plasma chamber in which said substantially controllable plasma is generated; an anode; at least one adjustable cathode disposed in said plasma chamber, wherein said at least one adjustable cathode is movable to establish a gap between said anode and said at least one adjustable cathode; a power source coupled to said anode and said at least one adjustable cathode for providing a voltage across said anode and said at least one adjustable cathode; a plasma gas inlet for introducing a plasma gas from a plasma gas source into said plasma chamber at a plasma gas flow rate; and at least one sensor for detecting and monitoring conditions within said plasma chamber, said sensor being integral to said plasma chamber; and

b) a second chamber in fluid communication with said plasma chamber through an exit port, wherein said second chamber is maintained at a second pressure that is less than a first pressure in said plasma chamber, and wherein said substantially controllable plasma flows from said plasma chamber into said second chamber through said exit port.

34. (Original) The apparatus according to Claim 33, wherein said apparatus comprises a first plasma source and a second plasma source, wherein said first pressure of said plasma gas in said plasma chamber in said first plasma source and said first pressure of said plasma gas in said plasma chamber in said second plasma source are adjustable with respect to each other.

35. (Original) The apparatus of Claim 33, wherein said plasma gas inlet further includes means for controlling a flow of said plasma gas into said at least one plasma chamber.

36. (Currently amended) The apparatus of ~~Claim 33~~ Claim 35, wherein said means for controlling said flow comprises at least one mass flow controller.

37. (Original) The apparatus according to Claim 33, further comprising a pressure means for moving said at least one adjustable cathode, said pressure means being coupled to said adjustable cathode.

38. (Original) The apparatus according to Claim 37, wherein said pressure means is a pressure plate.

39. (Original) The apparatus according to Claim 37, wherein said pressure means is a pneumatic drive.

40. (Original) The apparatus according to Claim 33, further comprising a screw feed for moving said at least one adjustable cathode, said screw feed being coupled to said adjustable cathode.

41. (Original) The apparatus according to Claim 33, wherein said at least one adjustable cathode comprises a wire.

42. (Original) The apparatus according to Claim 41, further comprising a wire feed for moving said at least one adjustable cathode, said wire feed being coupled to said adjustable cathode.

43. (Original) The apparatus according to Claim 33, wherein said at least one sensor includes a pressure sensor, said pressure sensor being in fluid communication with said plasma chamber.

44. (Original) The apparatus according to Claim 43, wherein said pressure sensor comprises a transducer.

45. (Original) The apparatus according to Claim 33, wherein said at least one sensor includes one of a current sensor and a voltage sensor disposed in an electrical circuit between said power source and said at least one adjustable cathode.

46. (Original) The apparatus according to Claim 33, wherein said power source is a DC power source.

47. (Original) The apparatus according to Claim 46, wherein said power source provides up to 100 amps of current at up to about 50 volts.

48. (Original) The apparatus according to Claim 33, further including a control system for moving said at least one adjustable cathode, wherein said control system is coupled to said at least one sensor, said power source, and said at least one adjustable cathode, wherein said controller receives an input on said conditions in said plasma chamber and moves said at least one adjustable cathode to establish a predetermined gap between said anode and said at least one adjustable cathode based upon said input.

49. (Original) The apparatus according to Claim 33, wherein said exit port comprises an orifice formed in said anode.

50. (Original) The apparatus according to Claim 33, wherein said exit port comprises a floating cascade plate.

51. (Original) The apparatus according to Claim 33, wherein said exit port comprises a floating wall of one of said plasma chamber and said second chamber.

52. (Original) The apparatus according to Claim 33, wherein said first pressure is at least about 0.1 atmosphere.

53. (Original) The apparatus according to Claim 52, wherein said first pressure is about 1 atmosphere.

54. (Original) The apparatus according to Claim 33, wherein said second pressure is less than about 1 torr.

55. (Original) The apparatus according to Claim 54, wherein said second pressure is less than about 100 millitorr.

56. (Original) The apparatus according to Claim 33, wherein said apparatus is an apparatus for plasma treating a surface of an article with said substantially controllable plasma, wherein said article is disposed in said second chamber such that said substantially controllable plasma generated by said at least one expanding thermal plasma source exits said plasma chamber through said exit and impinges upon said surface.

57. (Original) The apparatus according to Claim 56, further including at least one reactant gas injector disposed in said second chamber proximate to said exit port of each of said at least one expanding thermal plasma source, wherein said reactant gas injector directs a reactant gas into said substantially controllable plasma, and wherein said

reactant gas reacts with said substantially controllable plasma to form a coating on said surface of said article.

58. (Original) The apparatus according to Claim 33, wherein said apparatus comprises a first expanding thermal plasma source and a second expanding thermal plasma source, wherein said voltage across said cathode and said anode in said first expanding thermal plasma source and said voltage across said cathode and said anode in said second expanding thermal plasma source are adjustable with respect to each other.

59. (Withdrawn) A method for generating a substantially controllable plasma, the method comprising the steps of:

a) providing at least one plasma source, the at least one plasma source comprising: a plasma chamber; an anode; at least one adjustable cathode disposed in the plasma chamber; a power source coupled to the anode and the at least one adjustable cathode; a plasma gas inlet; and at least one sensor;

b) providing a plasma gas through the plasma gas inlet to the plasma chamber in each of the at least one plasma source;

c) generating a plasma in the plasma chamber;

d) monitoring at least one parameter within the plasma chamber; and

e) controlling the plasma, wherein the plasma is controlled by adjusting conditions within the plasma chamber, based upon the monitoring of the at least one parameter.

60. (Withdrawn) The method according to Claim 59, wherein the step of providing at least one plasma source comprises providing at least one expanding thermal plasma source.

61. (Withdrawn) The method according to Claim 59, wherein the step of controlling the plasma comprises moving at least one of the adjustable cathode and the anode to establish a gap between the anode and the at least one adjustable cathode.

62. (Withdrawn) The method according to Claim 59, wherein the step of controlling the plasma comprises controlling a pressure of plasma gas within the plasma chamber.

63. (Withdrawn) The method according to Claim 62, wherein the step of controlling the plasma comprises controlling a pressure of plasma gas within the plasma chamber comprises controlling a first pressure of plasma gas in a first plasma source and a second pressure of the plasma gas in a second plasma source.

64. (Withdrawn) The method according to Claim 59, wherein the step of controlling the plasma comprises controlling a voltage across the at least one adjustable cathode and the anode.

65. (Withdrawn) The method according to Claim 59, wherein the step of controlling a voltage across the at least one adjustable cathode and the anode comprises controlling a voltage across the at least one adjustable cathode and the anode in a first expanding thermal plasma source and controlling a voltage across the at least one adjustable cathode and the anode in a second expanding thermal plasma source.

66. (Withdrawn) A method for treating an article using a substantially controllable expanding thermal plasma, the method comprising the steps of:

a). providing at least one expanding thermal plasma source, wherein the at least one expanding thermal plasma source comprises: a plasma chamber; an anode; at least one adjustable cathode disposed in the plasma chamber; a power source coupled to the anode and the at least one adjustable cathode; a plasma gas inlet; and at least one sensor;

b). providing a plasma gas through the plasma gas inlet to the plasma chamber in each of the at least one expanding plasma source;

c). generating a plasma in the plasma chamber;

d). monitoring at least one parameter within the plasma chamber; and

e). controlling the plasma, wherein the plasma is controlled by adjusting conditions within the plasma chamber, based upon the monitoring of the at least one parameter;

f). forming an expanding thermal plasma by expanding the plasma through an exit port into a second chamber in fluid communication with the plasma chamber, wherein the second chamber contains the article and is maintained at a second pressure that is less than a first pressure in said plasma chamber; and

g) impinging the expanding thermal plasma on a surface of the article, thereby treating the article.

67. (Withdrawn) The method according to Claim 66, wherein the step of controlling the plasma comprises moving at least one of the adjustable cathode and the anode to establish a gap between the anode and the at least one adjustable cathode.

68. (Withdrawn) The method according to Claim 66, wherein the step of controlling the plasma comprises controlling a pressure of plasma gas within the plasma chamber.

69. (Withdrawn) The method according to Claim 68, wherein the step of controlling the plasma comprises controlling a pressure of plasma gas within the plasma chamber comprises controlling a first pressure of plasma gas in a first plasma source and a second pressure of the plasma gas in a second plasma source.

70. (Withdrawn) The method according to Claim 66, wherein the step of controlling the plasma comprises controlling a voltage across the at least one adjustable cathode and the anode.

71. (Withdrawn) The method according to Claim 70, wherein the step of controlling a voltage across the at least one adjustable cathode and the anode comprises controlling a voltage across the at least one adjustable cathode and the anode in a first expanding thermal plasma source and controlling a voltage across the at least one adjustable cathode and the anode in a second expanding thermal plasma source.

72. (Withdrawn) The method according to Claim 66, the step of impinging the expanding thermal plasma on a surface of the article comprises:

a) injecting at least one reactant gas into the expanding thermal plasma; and

b) depositing a coating on the surface of the article.

73. (Withdrawn) An article having at least one coating disposed on a surface of the article, wherein the at least one coating is substantially uniform and has a selected property that exhibits a variation of less than about 10% across the surface of said article, the coating being deposited on the surface by:

a) providing at least one expanding thermal plasma source, wherein the at least one expanding thermal plasma source comprises: a plasma chamber; an anode; at least one adjustable cathode disposed in the plasma chamber; a power source coupled to the anode and the at least one adjustable cathode; a plasma gas inlet; and at least one sensor;

b) providing a plasma gas through the plasma gas inlet to the plasma chamber in each of the at least one expanding plasma source;

c) generating a plasma in the plasma chamber;

d) monitoring at least one parameter within the plasma chamber; and

e) controlling the plasma, wherein the plasma is controlled by adjusting conditions within the plasma chamber, based upon the monitoring of the at least one parameter;

f) forming an expanding thermal plasma by expanding the plasma through an exit port into a second chamber in fluid communication with the plasma chamber, wherein the second chamber contains the article and is maintained at a second pressure that is less than a first pressure in said plasma chamber;

g) injecting at least one reactant gas into the expanding thermal plasma; and

h) depositing a coating on the surface of the article.

74. (Withdrawn) The article according to Claim 73, wherein the at least one coating comprises one of an abrasion-resistant coating, an ultraviolet filtering coating, an

infrared reflective coating, an oxygen-barrier coating, moisture-barrier coating, an anti-reflective coating, a conductive coating, an adhesion layer, and combinations thereof.

75. (Withdrawn) The article according to Claim 73, wherein the selected property of the at least one coating is one of coating thickness, abrasion resistance, ultraviolet radiation absorbance, infrared radiation reflectivity, modulus, hardness, oxygen permeability, water permeability, adhesion, surface energy, thermal conductivity, and electrical conductivity.